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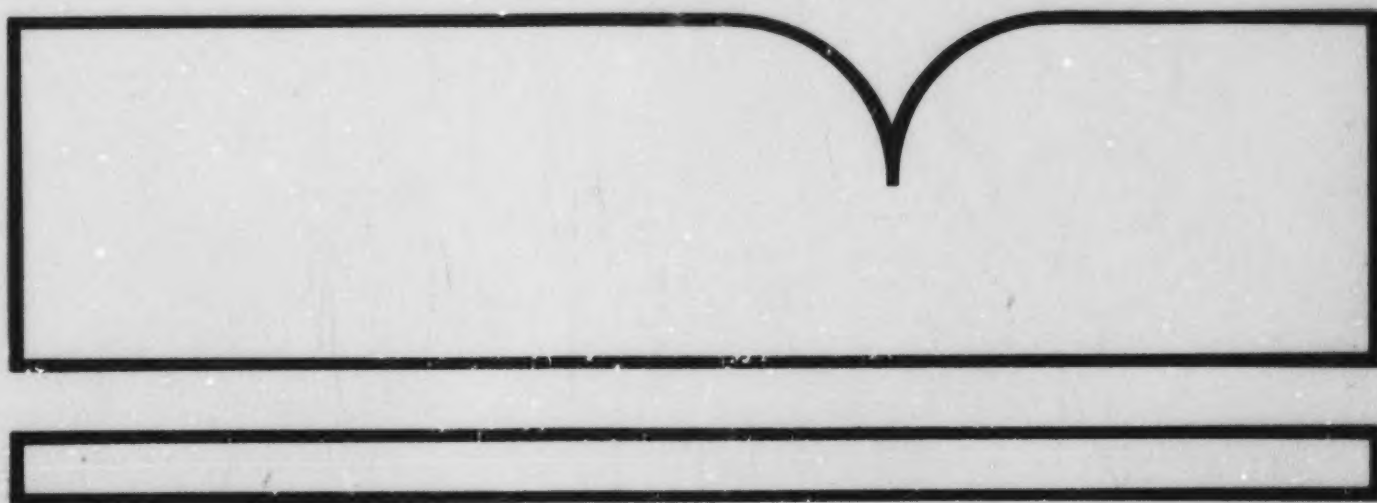
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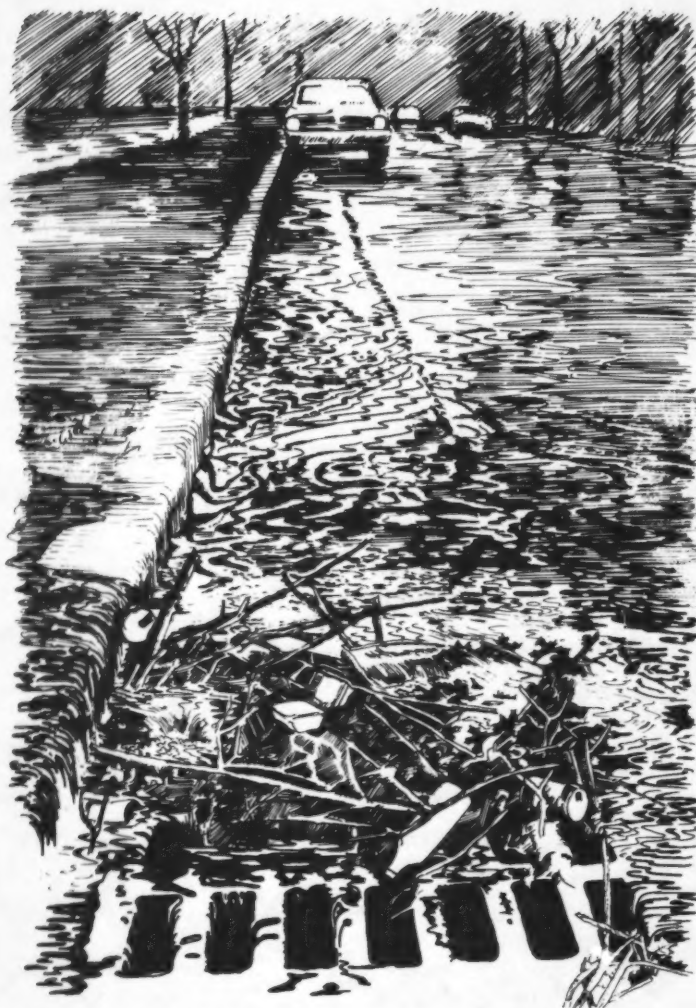
1983



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# Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin



## Executive Summary

Wisconsin Department of Natural Resources  
Madison, Wisconsin  
1983

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| <b>16. Abstract (Limit: 200 words)</b><br>The Executive Summary provides a brief overview of the project, the principle objectives, the methodology and the conclusions reached and recommendations. The three principle objectives were to: 1) characterize the urban stormwater quality of a major Midwestern city; 2) evaluate the effectiveness, feasibility, and cost of street sweeping, catchbasin cleaning and stormwater storage basins as urban stormwater management practices; and 3) to evaluate the various sources of urban stormwater contaminants. |                      |                                                         |                                                                       |
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| Hydrology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Water pollution      | Storms                                                  | Civil Engineering                                                     |
| Urban development                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Water resources      | Regional planning                                       |                                                                       |
| Watersheds                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Sedimentation        | Urban planning                                          |                                                                       |
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| Runoff                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Soil Erosion         | Storm Drains                                            |                                                                       |
| Streamflow                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Water Quality        | Urbanization                                            |                                                                       |
| Stream pollution                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Sediments            | Land use                                                |                                                                       |
| Rainfall                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Sediment Transport   |                                                         |                                                                       |
| Snowmelt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Suspended Solids     |                                                         |                                                                       |
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**EVALUATION OF URBAN NONPOINT SOURCE  
POLLUTION MANAGEMENT IN MILWAUKEE COUNTY, WISCONSIN**

**EXECUTIVE SUMMARY**

by

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Mike Bohn**

**In Cooperation With The  
Southeastern Wisconsin Regional Planning Commission**

for

**U. S. Environmental Protection Agency  
Region V  
230 South Dearborn Street  
Chicago, Illinois 60604  
Grant Number P005432-01-5**

## EXECUTIVE SUMMARY

### INTRODUCTION

This report presents findings, conclusions and recommendations from a study of the characteristics, sources and controls of urban stormwater pollution in Milwaukee, Wisconsin. This study was conducted by the Wisconsin Department of Natural Resources (WDNR), with major subcontracts to the U. S. Geological Survey (USGS), and to the Southeastern Wisconsin Regional Planning Commission (SEWRPC). It was funded largely by the U. S. Environmental Protection Agency (Grant No. 005432-01-5) as one of the 28 studies undertaken by the Nationwide Urban Runoff Program (NURP).

NURP was developed in 1978 to remedy the inadequacy of data regarding urban stormwater characteristics, impacts and controls. The 28 NURP studies are located around the United States, and represent a variety of regional and hydrological conditions. This project was chosen to represent conditions around the Great Lakes.

### Objectives

This study has had three principle objectives: 1) to characterize the urban stormwater quality of a major Midwestern city, 2) to evaluate the various sources of urban stormwater contaminants, and 3) to evaluate the effectiveness, feasibility, and cost of street sweeping, catch basin cleaning and stormwater storage basins as urban stormwater management practices. Pursuant to these objectives, a number of related tasks were developed and executed.

### Methodology

To characterize urban stormwater quality, stormwater discharge from eight paired basins in Milwaukee County was monitored. The eight paired basins represent four major urban land uses: commercial, high and medium density residential areas and parking lots. The basins are small (less than 62 acres), relatively homogeneous, and are drained by separate storm sewers. The paired basins are either contiguous, or within a quarter mile of each other. Event runoff was monitored at each site using one minute stage recorders and automatic flow proportional composite samplers. A single event mean concentration and total event load was determined for each parameter that was analyzed for each monitored event. A total of 450 events at the eight stations were monitored. Rainfall at each station was also recorded at one minute intervals.

To evaluate the various sources of urban stormwater contaminants, a multifaceted monitoring program was developed. A comprehensive street surface sampling program was maintained at one of each of the paired water quality stations. A total of 554 street surface contaminant samples were collected, including 142 accumulation, 113 street sweeper removal, and 19 rainfall wash-off evaluations. In addition, atmospheric wetfall and dryfall monitoring was

conducted at eight locations in or nearby the water quality sites. A total of 242 wetfall and 112 dryfall atmospheric samples were collected. Rooftop runoff from three houses was monitored, and a total of 48 composite rooftop runoff samples were collected. Through an analysis of stormwater contributions from street surfaces, rooftops, and precipitation, a mass balance of stormwater contaminant sources was achieved.

To evaluate the effects of street sweeping as an urban stormwater management practice, a threefold approach was taken. First, an evaluation of in-situ street sweeper contaminant removal was conducted, as mentioned previously. Secondly, the water quality impacts of street sweeping were evaluated through use of a conventional test and control experimental design. Within each basin pair, one watershed was designated as the test site, and the other the control site. Street sweeping in the control sites was maintained at the usual or baseline frequencies that are normally maintained by the respective municipalities for aesthetic reasons. Street sweeping in the test sites alternated between corresponding baseline frequencies (control periods) and accelerated frequencies (test periods). By comparing the stormwater quality between test and control sites between test and control periods, an evaluation of the water quality impacts of street sweeping was achieved. Thirdly, two models were developed in this project to extrapolate the findings of this project to other areas and/or sweeping frequencies. To compliment the technical findings of this study, an economic evaluation of street sweeping was also conducted.

The findings of this study were integrated with those of other NURP studies and literature sources to evaluate the feasibility and application of street sweeping, stormwater storage basins (detention and retention basins) and catch basin cleaning as control measures in urban areas. The cost and pollutant removal estimates determined for these control measures were applied to three urban drainage areas in southeastern Wisconsin to evaluate the cost, pollution loading reductions and cost effectiveness which may be expected if these control measures were implemented in urban areas.

#### Project Responsibilities

This project was conducted by the WDNR, with major subcontracts to USGS and SEWRPC. The WDNR was responsible for the project administration and the ultimate completion of the project objectives. Department personnel conducted the street surface, atmospheric wet and dry, and the rooftop monitoring programs. In addition, they were responsible for the data management and analysis for these programs as well as for the water quality evaluation. They also developed one of the two urban runoff/street sweeping models produced in this study. The USGS performed the rainfall and runoff monitoring, the hydrologic analysis, and the preparation and sieving of the street surface samples. SEWRPC performed the site inventories, the economic evaluation of street sweeping, the application of the study results to select areas within southeastern Wisconsin, and the public participation efforts. Additionally, the Wisconsin State Lab of Hygiene performed the chemical analyses for the various monitoring programs. Lastly, Professor Vladimir Novotny from Marquette University developed the other model used in this study.

### Scope

This project began in July of 1979, and was completed in July of 1983. It was a comprehensive evaluation of urban stormwater problems and concerns. The results of this study can be extrapolated to urban areas of the Great Lakes, and to other areas of similar meteorologic, atmospheric and cultural conditions. This report will be of use to city and state planners and engineers, and to those with a need to develop a better understanding of the urban runoff impacts and controls of existing or planned urban development.

### Report Structure

This report is presented in three volumes. Volume I presents the technical findings, conclusions and recommendations pursuant to the three primary objectives listed earlier.

Volume II contains the economic evaluation of street sweeping. In addition, the cost and pollutant abatement effectiveness of stormwater storage basins (detention and retention basins) and catch basin cleaning are presented. The volume also evaluates the applicability, costs, and pollutant removal rates which may be expected with the application of improved street sweeping, modified detention and retention basins and catch basin cleaning in three urban drainage areas in southeastern Wisconsin.

Volume III contains all of the materials and methods of the entire project, as well as other types of ancillary and supportive information.

### CONCLUSIONS AND RECOMMENDATIONS

#### Characteristics of Urban Stormwater

1. Among the urban areas of this study, stormwater runoff concentrations and loads for total lead and suspended solids were highest from the commercial areas, followed by high density and medium density residential areas, respectively. Annual loads of suspended solids from the high density residential areas and the commercial areas are two and five times higher respectively than from the medium density residential areas, and annual loads of total lead were four and thirteen times higher, respectively. A ranking of pollutant loads for urban land uses monitored in this study and previous studies in the Milwaukee area indicates that commercial, industrial and freeway land uses are most critical. Because of the wide range in pollutant loads from various urban land uses, an urban nonpoint source pollution control program should be tailored to the specific land uses where it can be applied most cost-effectively.
2. Fecal coliform counts in urban runoff usually greatly exceed safe full body contact recreational water use (bathing water) criteria. The high fecal counts suggest that body contact be limited in urban streams and that levels of fecal coliforms in receiving waters be closely monitored following rainfall.

### Impacts of Urban Stormwater

1. This project did not collect any water quality data in the receiving streams, but results from previous monitoring programs on the Menomonee River were used to evaluate the impact of urban stormwater in Milwaukee County. The quality of the Menomonee River decreases as it flows from its agricultural headwaters through Milwaukee to Lake Michigan. This degradation is reflected by the decreasing numbers of fish and the increasing level of pollutants in the water and bottom sediments. The fish population may be responding to a number of variables, including accumulated toxins in bottom sediments and changes in the hydrology and morphology of the river. Yet, in the absence of significant known point sources of toxins and solids, the dramatic decline in the quality of the river system as it flows through Milwaukee demonstrates that urban stormwater can seriously degrade the quality, aquatic viability, and beneficial uses of receiving waters. To restore the full quality of this river system, an urban as well as an agricultural nonpoint source management program is needed.
2. Urban and agricultural land uses in Wisconsin generate similar stormwater loads of suspended solids and total phosphorus on a unit area basis. Agricultural land uses generate less volume of runoff but higher concentrations of these pollutants than urban areas. Both stormwater loads and concentrations of lead, and of most other heavy metals, are much higher from urban areas than from agricultural areas. For an effective statewide nonpoint source pollution control program, urban areas as well as agricultural areas need to be managed properly.
3. The amounts of total phosphorus and BOD discharged from residential areas via treated secondary wastewater is greater than the amounts contained in stormwater runoff. However, the suspended solids discharged in residential stormwater runoff is greater than in treated secondary effluent. The relative sources of specific pollutants in receiving waters need to be addressed when reviewing water quality problems and considering alternative management programs.

### Sources of Urban Stormwater Contaminants

1. Most of the sediments and toxic metals in urban runoff originate in wash-off from streets. However, other than in the fall, total phosphorus loads observed in individual stormwater events are generally much greater than total loads observed in the streets, indicating that most phosphorus originates from lawns and trees. The differences in relative sources of stormwater contaminants strongly affects the water quality impacts of street sweeping on those contaminants.
2. Street loads of sediment and toxic metals are at their annual peak at the onset of winter snowmelt and spring rainfalls. If not swept up, this residue, which has accumulated throughout the winter, is quickly washed into receiving waters by spring rains. As much as one-fifth to one-third of total annual stormwater load of sediment may occur in the first month of spring runoff.

Once the streets are "cleaned" of winter residues, however, (by repeated sweeping and/or rainfall washoff) street loads fluctuates between the limits of an upper and lower bounds unique to each site. The lower bounds are dependent primarily on street surface texture and condition. They represent a reservoir of street loads that is the cleanest condition expected for the street. Street sweeping at this level is not effective at further reducing street loads and rainfalls at this level tend to wash or carry as much material onto the street as off of it. The upper bounds are dependent upon land use intensity, traffic patterns, and street surface texture and conditions, which combine to effect the rate of accumulation of street surface material. They are approximately two to three times the level of the lower bounds, and are the maximum street load level observed in this study before street sweeping, rainfall or winds swept, washed or otherwise removed a portion of the street load. Street loads of total solids ranged from 5 to 15 grams per curb meter (17.7 to 53.2 lbs per curb mile) for a medium density residential area and 40 to 80 grams per curb meter (141.9 to 283.8 lbs per curb mile) for a commercial area.

3. Atmospheric dry deposition of solids, lead and COD increases with increasing residential density and intensity of commercial and industrial land uses. Atmospheric dry deposition rates of sulfate and lead are constant throughout the year, showing little seasonal variation. The wet and dry atmospheric deposition of solids and phosphorus is highest in spring and lowest in winter, probably related to the seasonal variation in exposed soil available to wind erosion.
4. No spatial or land use related variations were observed among concentrations of contaminants in rainfall. The monitored acidity and sulfate rainfall concentrations are slightly higher in the Milwaukee area than averages from other sites monitored in Wisconsin. For low intensity land uses, such as medium density residential areas, contaminants in rainfall can provide as much as 10 to 20 percent of the total stormwater loads of some pollutants. These contributions decrease with increasing urban density, because washoff from streets, parking lots and roof tops become more important. Management alternatives to reduce this portion of the pollutants carried by stormwater could be more effective if directed at reducing the sources of atmospheric contamination, such as fugitive dust (wind erosion) and industrial and automotive emissions.
5. Rooftop runoff contaminant concentrations generally increase with increasing residential density and the intensity of commercial and industrial land uses. Despite the increasing concentrations however, the relative contribution of rooftop runoff contaminants to total stormwater pollutant loads decrease because of the importance of other contaminant sources associated with these land uses. Galvanized steel eaves troughs and downspouts on residential roofs are major sources of zinc. For medium density residential areas, an average of 23 percent of the water, 7 percent of the suspended solids and virtually all of the zinc in stormwater came from rooftops. Management of residential rooftop runoff through removal of zinc sources, and routing of downspout outlets to pervious areas could reduce stormwater volumes and the concentrations of some stormwater contaminants.

6. In medium and high density residential areas, runoff originating from lawns is of the same order of magnitude as that from connected rooftops, roughly 10-20 percent of the total runoff for most rainfalls less than 2 inches. In commercial areas, runoff from pervious surfaces is less than 5 percent of the total runoff, while runoff from connected rooftops is 30-40 percent of the total. The control of runoff from lawns should have a lower priority than other sources in an established urban area.

#### Management Alternatives for Urban Stormwater

1. Because of the extreme variability in urban stormwater quality, and of the difficulties in taking comprehensive and representative samples, this project was unable to statistically demonstrate a water quality impact due to accelerated street sweeping. Rather, the projected water quality benefits of street sweeping were derived through the use of two models developed in this study.

Street sweeping is most effective as a stormwater pollution control practice under two conditions: 1) early in the spring when streets are laden with winter residue, and 2) in the fall, following leaf fall. Following snowmelt, an intensive street sweeping program to clean city streets as early as possible is recommended. An area may need to be swept more than once to be adequately cleaned. Early intensive street sweeping may reduce the total stormwater pollutant load for the first month of the season by as much as 50 percent. In the fall, in areas with heavy leaf accumulations, intensive street cleaning and leaf pick up are recommended. Use of leaf rakes and/or vacuum street cleaners may be used to augment or replace sweepers. Concomitant efforts should also be made to encourage residents to bag or pile their leaves next to the curb, rather than raking them into the gutters.

For most urban areas, street sweeping does not appear to be a effective pollution control practice from late spring (once the streets are cleaned of accumulated winter loads) until early fall (prior to the onset of leaf fall). Intensive street sweeping (two or three times per week) during this period will result in limited stormwater pollution reductions, but it is doubtful that it will exceed ten percent.

2. Adequately sized and properly designed and operated retention basins or modified detention basins could be expected to remove at least 50 percent and as much as 95 percent of the pollutants entering the basin. The pollutant removal for a properly sized basin is much higher than for an accelerated street cleaning program. The availability of suitable open space for stormwater storage may be the limiting factor determining the use of stormwater storage as a pollution control method, however. In some instances only a small portion of a watershed would drain to a basin, and as little as five percent of the total pollutant loadings from a drainage area could be removed.
3. Urban areas with the most hydrologically impervious surfaces generate the most stormwater runoff. This increased runoff not only creates greater downstream flooding problems, but also carries with it more stormwater

pollution. The hydrologic response of an area may be the most significant factor determining the subsequent level of stormwater pollution. Consequently, stormwater management is an essential part of any urban stormwater control program particularly in developing areas. In many established urban areas, simple redirection of rooftop downspouts away from the stormwater conveyance system may reduce yields of stormwater runoff and associated pollutants.

#### Feasibility and Application of Urban Nonpoint Source Water Pollution Treatment Measures

1. The analysis of urban nonpoint source control measures has demonstrated that storage basins can be used to achieve a significant level of pollutant loading reduction. Storage basins at three urban drainage areas in southeastern Wisconsin achieved 10, 25, and 93 percent reductions in total solids annual loadings and 5, 19, and 77 percent reductions in total lead loadings. Street sweeping achieved approximately 3, 7, and 9 percent reductions in total solids loadings and approximately 3, 12, and 17 percent reductions in total lead loadings. The street sweeping achieved greater reductions in total lead loadings than the storage basins only for the drainage area with little available open space except at sites with relatively low pollutant loadings. Because of the variable cost and pollutant removal levels, care must be taken to select the appropriate control measure which achieves the desired level of pollution control in a cost effective manner.
2. Stormwater storage was found to be a much more cost effective method of removing solids than an accelerated street sweeping program. The cost effectiveness of stormwater storage at three urban drainage areas ranged from \$0.15 to \$0.26 per pound of solids removed versus \$0.39 to \$0.68 for a street cleaning program with accelerated cleaning frequencies in March and October. Compared to stormwater storage alone, the combination of street cleaning and storage did not significantly increase solids removal, while it diminished cost effectiveness. If suitable open land is available stormwater storage may be the preferred method of stormwater management in some established urban areas.
3. The cost effectiveness analyses conducted in this study indicate that the most cost effective nonpoint source control alternatives (street sweeping or storage basins) for three typical urban drainage areas would have an average cost of \$0.20 per pound of solids removed, \$3.45 per pound of volatile suspended solids removed, \$12.17 per pound of nitrogen removed, \$144 per pound of phosphorus removed, and \$387 per pound of lead removed. The costs of management practices vary with location, and these cost numbers should only be used to provide a preliminary estimate of the cost associated with a stormwater management program.